ocean explorer
oceanexplorer.noaa.gov

Medicines from the Deep Sea: Exploration of the Gulf of Mexico

Living by the Code

Focus
Functions of cell organelles and the genetic code in chemical synthesis

Grade Level
7–8 (Life Science)

Focus Question
What is the overall process through which cells manufacture chemicals?

Learning Objectives
Students will be able to explain why new drugs are needed to treat cardiovascular disease, cancer, inflammation, and infections.

Students will be able to infer why sessile marine invertebrates appear to be promising sources of new drugs.

Students will be able to explain the overall process through which cells manufacture chemicals.

Students will be able to explain why it may be important to be able to synthesize new drugs, rather than relying on natural production of the drugs.

Materials
- ❒ Writing paper
- ❒ Pencils or pens
- ❒ Marker board, blackboard, or overhead projector with transparencies for group discussions

Audio/Visual Materials
None

Teaching Time
One or two 45-minute class periods

Seating Arrangement
Groups of 4-6 students

Maximum Number of Students
30

Key Words
Cardiovascular disease
Cancer
Arthritis
Natural products
Sponge
Tunicate
Ascidian
Bryozoan
Octocorals

Background Information
Despite the many advances of modern medicine, disease is still the leading cause of death in the United States. Cardiovascular disease and cancer together account for more than 1.5 million deaths annually (40% and 25% of all deaths, respectively). In addition, one in six Americans have some form of arthritis, and hospitalized patients are increasingly threatened by infections that are resistant to conventional antibiotics. The cost of these diseases is staggering: $285 billion per year for cardiovascular disease; $107 billion per year for cancer; $65 billion per year for arthritis. Death rates, costs of treatment and lost productivity, and emergence of drug-resistant diseases all point to the need for

new and more effective treatments.

Most drugs in use today come from nature. Aspirin, for example, was first isolated from the willow tree. Morphine is extracted from the opium poppy. Penicillin was discovered from common bread mold. To date, almost all of the drugs derived from natural sources come from terrestrial organisms. But recently, systematic searches for new drugs have shown that marine invertebrates produce more antibiotic, anti-cancer, and anti-inflammatory substances than any group of terrestrial organisms. Particularly promising invertebrate groups include sponges, tunicates, ascidians, bryozoans, octocorals, and some molluscs, annelids, and echinoderms.

The list of drugs derived from marine invertebrates includes:
Ecteinascidin – Extracted from tunicates; being tested in humans for treatment of breast and ovarian cancers and other solid tumors

Topsentin – Extracted from the sponges *Topsentia genitrix*, *Hexadella* sp., and *Spongosorites* sp.; anti-inflammatory agent

Lasonolide – Extracted from the sponge *Forcepia* sp.; anti-tumor agent

Discodermalide – Extracted from deep-sea sponges belonging to the genus *Discodermia*; anti-tumor agent

Bryostatin – Extracted from the bryozoan *Bugula neritina*; potential treatment for leukemia and melanoma

Pseudopterosins – Extracted from the octocoral (sea whip) *Pseudopterogorgia elisabethae*; anti-inflammatory and analgesic agents that reduce swelling and skin irritation and accelerate wound healing

ω-conotoxin MVIIA – Extracted from the cone snail, *Conus magnus*; potent pain-killer

This list reflects an interesting fact about invertebrates that produce pharmacologically-active substances: most species are sessile; they are immobile and live all or most of their lives attached to some sort of surface. Several reasons have been suggested to explain why these particlar animals produce potent chemicals. One possibility is that they use these chemicals to repel predators, since they are sessile, and thus basically "sitting ducks." Since many of these species are filter feeders, and consequently are exposed to all sorts of parasites and pathogens in the water, they may use powerful chemicals to repel parasites or as antibiotics against disease-causing organisms. Competition for space may explain why some of these invertebrates produce anti-cancer agents: if two species are competing for the same piece of bottom space, it would be helpful to produce a substance that would attack rapidly dividing cells of the competing organism. Since cancer cells often divide more rapidly than normal cells, the same substance might have anticancer properties.

The goal of the 2003 Medicines from the Deep Sea Expedition is to discover new resources with pharmaceutical potential in the Gulf of Mexico. To achieve this goal, the expedition will:
- collect selected benthic invertebrates from deep-water bottom communities in the Gulf of Mexico (sponges, octocorals, molluscs, annelids, echinoderms, tunicates), identify these organisms, and obtain samples of DNA and RNA from the collected organisms;
- isolate and culture microorganisms that live in association with deep-sea marine invertebrates;
- prepare extracts of benthic invertebrates and associated microorganisms, and test these extracts to identify those that may be useful in treatment of cancer, cardiovascular disease, infections, inflammation, and disorders of the central nervous system;
- isolate chemicals from extracts that show pharmacological potential and determine the structure of these chemicals;

- further study the pharmacological properties of active compounds; and
- develop methods for the sustainable use of biomedically important marine resources.

The last objective is particularly important, since many potentially useful drugs are present in very small quantities in the animals that produce these drugs. This makes it impossible to obtain useful amounts of the drugs simply by harvesting large numbers of animals from the sea. Some alternatives are chemical synthesis of specific compounds, aquaculture to produce large numbers of productive species, or culture of the cells that produce the drugs. Some techniques for producing specific drugs are based on the cells' own machinery for chemical synthesis: enzymes, guided by information contained in the cells' DNA and RNA.

This activity is designed to highlight the relationships among cell organelles and the operation of the genetic code in chemical synthesis.

Learning Procedure

[NOTE: This lesson is based upon activities designed by Helga Burns, Patricia Colbert, Phillis Unbehagen, and Lynn Gordon while participating in the 1993 Woodrow Wilson Biology Institute. These activities are used with permission from the Woodrow Wilson National Fellowship Foundation. Visit http://woodrow.org *for information on other activities and current programs.]*

1. Download the following activities:
   - "The Spanish Omelet" (http://www.woodrow.org/teachers/bi/1993/the_spanish.html)
   - "Cracking the Code" (http://www.woodrow.org/teachers/bi/1993/cracking.html)
   - "Creative Expressions–Protein Synthesis" (http://www.woodrow.org/teachers/bi/1993/creative_exp.html)

2. Review the importance of finding new drugs for the treatment of cardiovascular disease, cancer, inflammatory diseases, and infections. Describe the potential of marine communities as sources for these drugs, and briefly discuss some potentially useful drugs that have been discovered from these communities. Ask students to list some reasons that these kinds of drugs might be found primarily among sessile invertebrates. Briefly introduce the objectives of the 2003 Medicines from the Deep Sea Expedition.

   Read the Spanish Omelet story, and review the functions of the cell nucleus, chromosomes, genes, ribosomes, DNA, and RNA, as well as the meaning of transcription, translation, genotype, and phenotype.

3. Have students do Activity One in "Cracking the Code" to review the concept of the triplet codon and how information contained in the DNA molecule is decoded. In this activity, students are given a brief message written in the "genetic code," divide the message into triplet codons, then decode the message using a master list of codons and their equivalent alphabetic characters. Students then use the same code to write a message to someone else in the class. [NOTE: The activity provides a version of the code for reading and a version for writing. The code is the same in both versions, but the order of the characters is re-arranged to make it easier to encode or decode a message.]

4. Tell students that their assignment is to make a three-dimensional, moveable model of protein synthesis that illustrates all of the processes involved from replication to production of the protein. This may be a group or individual project. Allow one to two weeks for students to complete their models. You may want to offer the option to create a written creative project as an alternative to the model. The "Creative Expressions" activity has a great example.

5. Lead a discussion of why understanding how cells manufacture chemicals could be useful in the search for new drugs. Students should understand that natural sources of many drugs are likely to be

very limited, so synthetic techniques are needed to produce these drugs in large quantities. The processes that take place during chemical synthesis by cells can be valuable models for these techniques.

Discuss the process of developing a useful drug from a marine organism. The first step, of course, is to locate a promising candidate. This involves "prospecting" among many different species, though past experience suggests some groups (sessile invertebrates) that may be particularly promising. Extracts of each species are prepared, usually by grinding tissue from the organisms in organic solvents. Next, the extracts are tested for pharmacological activity through a series of bioassays (for example, finding out whether an extract can kill leukemia cells or reduce inflammation). When an extract is found to have positive biological activity, the active substance in the extract is isolated and identified. If the isolated chemical turns out to be new, the next step is to test the chemical in animal models (for example, mice with tumors). If animal testing is successful, the chemical may be approved for evaluation in humans. If the chemical is effective in humans without toxic side effects, it may be approved as a new drug. The entire process can take a lot of time and money; a new anti-cancer drug may require 10 – 20 years and an average of $40,000,000 to develop to the point of commercialization.

The BRIDGE Connection

www.vims.edu/bridge/ – Click on "Ocean Science" in the navigation menu to the left, then "Chemistry" for resources on drugs from the sea. Click on "Ecology" then deep sea for resources on deep-sea communities. Click on "Human Activities" then "Technology" then "Biotechnology" for resources on biotechnology.

The "Me" Connection

Have students write a short essay on the importance of protecting species like sessile invertebrates.

Connections to Other Subjects

English/Language Arts; Chemistry

Evaluation

The following activities provide opportunities for assessment:

- Have students prepare a list identifying cell organelles and their analogies in the "Spanish Omelet" story of Step 2.
- Have students submit their decoded messages in Step 3.
- Models or other creative products prepared in Step 4.

Extensions

Log on to http://oceanexplorer.noaa.gov to keep up to date with the latest discoveries of the 2003 Medicines from the Deep Sea Expedition.

Visit http://www.woodrow.org/teachers/bi/1993/ for more activities related to biotechnology from the 1993 Woodrow Wilson Biology Institute.

Resources

http://oceanica.cofc.edu/activities.htm – Project Oceanica website, with a variety of resources on ocean exploration topics

http://www.science.fau.edu/drugs.htm – An overview article on drugs from the sea

Faulkner, D. J. 2000. Marine pharmacology. Antonie van Leeuwenhoek 77: 135-145. Available online at http://www.reefcheck.org/headlines/june/pdf/marine_pharmacology.pdf.

www.nci.nih.gov – Website of the National Cancer Institute

http://www.woodrow.org/teachers/bi/1993/ – Background and activities from the 1993 Woodrow Wilson Biology Institute on biotechnology

http://www.umsl.edu/~microbes/pdf/steriletechnique.pdf - Worksheet on sterile technique http://www.umsl.edu/~microbes/ – Website of the Science in the Real World: Microbes in Action project of the Department of Biology, University of Missouri, St. Louis

www.glogerm.com – Website of the Glo-Germ Company, with activity ideas related to microorganisms

http://ceprap.ucdavis.edu/acrobat/microkit_00.pdf – Activity manual developed during the 1996/97 teacher internship program of the Center for Engineering Plants for Resistance Against Pathogens at the University of California, Davis

http://spikesworld.spike-jamie.com/science/index.html — Website with lots of background and activities on multiple science topics, including microorganisms

National Science Education Standards

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard C: Life Science
- Structure and function in living systems
- Reproduction and heredity
- Diversity and adaptations of organisms

Content Standard F: Science in Personal and Social Perspectives
- Personal health
- Risks and benefits
- Science and technology in society

For More Information

Paula Keener-Chavis, National Education Coordinator/Marine Biologist
NOAA Office of Exploration
2234 South Hobson Avenue
Charleston, SC 29405-2413
843.740.1338
843.740.1329 (fax)
paula.keener-chavis@noaa.gov

Acknowledgements

This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL:
http://oceanexplorer.noaa.gov